

California Management Review

Stanford and Silicon Valley:
Lessons on Becoming a High-Tech Region

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One of the most striking economic developments of the latter half of the twentieth century was the appearance of clusters of high-tech firms in places such as Silicon Valley, Route 128, Research Triangle, and Bangalore. The age of globalization has paradoxically been accompanied by increased concentrations of related economic activities, what Ann Markusen refers to as “sticky places within slippery space.”¹ These new outposts on the frontier of the knowledge economy differed from previous clusters in many ways, including what they lacked: the need for immediate access to raw materials, to transportation nodes, and to skilled blue-collar labor. The rise of such clusters coincides with a dramatic shift of wealth creation from tangible assets (such as equipment) and natural resources to intangible (knowledge-based) assets. From the 1950s to the 1990s, the percentage of knowledge (as opposed to foodstuffs, materials, or minerals) in U.S. manufacturing value-added increased from 20 percent to 70 percent.²

One element that many successful high-tech regions share is one or more academic anchors, as the role of universities shifted from a relatively independent focus on the search for and dissemination of knowledge to a key position in what Etkowitz and Leydesdorff call a “triple helix of university-industry-government relations.”³ Route 128 has MIT and Harvard. Research Triangle has the University of North Carolina, Duke, and North Carolina State. Austin has the University of Texas. Bangalore has the Indian Institute of Technology. Silicon

The author thanks the following for their assistance and comments: Madeleine Adams, James Gibbons, Deborah Harrington, Richard Hoffman, Jeffrey Kottemann, Jodi Miklaszewski, William F. Miller, participants in the I&DS research colloquium of the Franklin P. Perdue School of Business at Salisbury University, Margaret Kimball at the Stanford University Archives, and two anonymous reviewers for the *California Management Review*. Research for this article was supported by a grant from the Salisbury University Foundation.

Valley has Stanford University. Although there is general agreement that research universities have been part of the picture in most high-tech regions, the key question lingers: What role should the academic anchor play in the development of a high-tech region?⁴ An illuminating case is the relationship between Stanford University and Silicon Valley during the two decades following World War II, when the region was developing into a high-tech cluster.

The most compelling form of university/industry relations is the academic anchor's nurturing of entrepreneurial enterprise, and companies spawned by Stanford University have attracted worldwide attention—for good reason. Recent studies indicate that even after excluding the impact of Hewlett-Packard (HP, the Valley's largest indigenous firm), more than half of the revenues of companies based in the Valley in both the 1980s and 1990s came from firms either started by Stanford students or professors or using technology developed at Stanford.⁵ One study suggests that nearly 2,000 of the San Francisco Bay Area's high-tech firms were founded by Stanford alumni or faculty.⁶ It seems at first as if one could draw a straight line from the start-ups of the 1930s (HP) and 1940s (Varian Associates) to more recent Stanford-influenced start-ups such as Cisco Systems, Silicon Graphics, Sun Microsystems, Google, and Yahoo.⁷ Can we?

I think not. I will show that during the crucial formative years of the Valley, Stanford University's principal contributions to achieving a critical mass of brains in local industry involved relations with satellite operations of firms headquartered elsewhere more than with local start-ups. Between 1945 and 1965, Stanford established four principal programs of outreach to the local business community: Stanford Research Institute (SRI), Stanford Industrial Park, the Honors Cooperative Program, and the Industry Affiliates Program.⁸ For each of the four outreach programs, source documents demonstrate that local start-ups represented a small minority of participants. Stanford's relationships with companies such as Lockheed, General Electric, and IBM were more representative during the 1950s and early 1960s than its relationships with companies such as Hewlett-Packard, Varian, and Watkins-Johnson.

The relationship between Stanford and Silicon Valley is especially important to understand correctly because of Silicon Valley's dramatic technological and economic success. Silicon Valley, the venture capitalist John Doerr announces to the world, represents "the largest legal creation of wealth in the history of the planet." If it were a separate country, Silicon Valley's economy would rank twelfth in the world.⁹ When developing regions look to Silicon Valley as a role model, they see the greatest incubator of start-up companies the world has seen. Estimates from 2002 suggest that the Valley is home to more than 22,000 high-tech firms, employing more than 500,000.¹⁰ By 1990, one-third of the largest high-tech companies created in the United States since 1965 were based in Silicon Valley.¹¹ Indeed, anthropologists have taken keen interest in the region, and the journalist David Kaplan

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notes that they "have taken to calling themselves 'entrepreneurialologists.'"¹² Much of the literature covering the past three decades of Silicon Valley's activity emphasizes entrepreneurship, and in looking at the Valley's recent past, entrepreneurship should be a major focus. Yet explanations of earlier developments in the Valley have often had a similar emphasis, downplaying the role of satellite operations of companies based elsewhere.¹³

The influence of Silicon Valley may be even greater than its economic performance because it has been used as a role model for other regions.¹⁴ The last quarter of the twentieth century saw the establishment of Silicon Forest (Portland), Silicon Mountain (Colorado Springs), Silicon Island (Singapore), Silicon Alley (Manhattan), Silicon Valley North (Ottawa), Silicon Glen (Scotland), Silicon Bog (Ireland), Silicon Wadi (Israel), and the like.¹⁵ In attempting to replicate Silicon Valley's formula for success, many regions have assumed that its centerpiece is a research university's active promotion of local high-tech entrepreneurship. Yet during the formative years of Silicon Valley, from the mid-1940s until the mid-1960s, Stanford's default mode of industrial outreach was to work with established firms, while its assistance of entrepreneurs was ancillary at best. In the key cases of Hewlett-Packard and Varian Associates, Stanford's promotion of entrepreneurship represented—at least for the university—a last resort.

3Com's founder, Bob Metcalfe, observes that "Silicon Valley is the only place on Earth not trying to figure out how to become Silicon Valley."¹⁶ If Silicon Valley is defined as an entrepreneurial high-tech region, and if the academic anchor's prescribed role is to promote entrepreneurship, then even during its formative years Silicon Valley was not trying to become Silicon Valley.

Literature Review, Silicon Valley

Scholarship on high-tech regions, clusters, industrial districts, and associated agglomeration economies has proliferated in the past two decades. Agglomeration theory, which suggests that economies external to the individual firm promote industry clustering, grows out of the work of the economist Alfred Marshall on specialty steel and industrial districts in nineteenth-century England. Marshall's work attracted renewed attention in the 1980s with the attention paid to agglomerations in northeastern Italy. More recently, the concept of the industrial district has been applied to modern high-tech regions, most notably by Michael Porter, who identified the "paradox" of the knowledge economy: "enduring competitive advantages in a global economy lie increasingly in local things—knowledge, relationships, motivation—that distant rivals cannot match."¹⁷ The necessary elements for creation of a high-tech cluster, recent developments in the global economy, new innovation capabilities, what government should—or should not—do, and the forms that clusters may take have been the central issues of this literature.¹⁸

Meanwhile, a growing literature surrounds what Philip Cooke calls the "master cluster" of Silicon Valley.¹⁹ Three scholars have made especially valuable

contributions to our understanding of Silicon Valley and its significance: AnnaLee Saxenian, Martin Kenney, and Stuart Leslie. In assessing the Valley, each focuses on a different primary unit of analysis. Saxenian focuses on the role of institutional and social networks in fostering innovation, Kenney on the institutional infrastructure that supports start-ups, and Leslie on the role of the university and the federal government in attracting resources to the region. Saxenian, Kenney, and Leslie all note the role of Stanford and/or Terman in promoting local start-ups, yet they provide divergent interpretations of the significance of Stanford University to the development of Silicon Valley.²⁰

Saxenian's comparison of Silicon Valley and Route 128 contrasts the organizational structures common to the two regions. Specialized production, permeable organization boundaries, and a sense of regional cooperation, she suggests, provided Silicon Valley with technological and market advantages compared to the vertical integration of organizations along Route 128.²¹ She notes that one difference between Silicon Valley and Route 128 is that Stanford has been "more deeply integrated into its regional surroundings" than MIT.²² In the three decades after World War II, she identifies "university research, military spending, and entrepreneurial risk-taking" as key factors in the Valley's rise.²³ She also highlights "institutional innovations" Stanford developed (SRI, the Honors Cooperative Program, and Stanford Industrial Park) and mentions some of the companies involved, but she does not assess the extent to which such programs targeted start-ups or established firms.²⁴ Saxenian provides valuable data showing how few high-tech firms existed in the Valley as of 1959; a closer look at the nature of Stanford's postwar industry relations helps to explain why.²⁵

Kenney argues that the nature of individual firms and their particular technological advances are not sufficient to explain the success of Silicon Valley.²⁶ Instead, he argues that the Silicon Valley difference has been the development of an infrastructure that enables the creation and growth of high-tech firms.²⁷ He draws a distinction between two spheres of the ecosystem. "Economy One" includes organizations (such as universities and existing companies) for which establishment of new companies is "a by-product of their normal activities."²⁸ "Economy Two" is the network of organizations (venture capitalist firms, law firms, and investment banks) for which establishment of new companies is their primary mission.²⁹ He argues that in Silicon Valley, Economy One was the primary enabler of start-ups during the 1950s because Economy Two did not yet exist.³⁰ The subsequent development of Economy Two reinforced a culture of risk-taking at the same time it lowered barriers to entry for new firms.³¹

More than Saxenian and Kenney, Leslie emphasizes the role of Stanford University and Frederick Terman in the development of the Valley.³² Leslie shows how during the two decades after World War II, a principal strategy for both Stanford University and local high-tech industry was to work with the government on state-of-the-art defense systems.³³ These parallel goals led to a symbiotic relationship between Stanford and local high-tech industry, with a steady flow of personnel and ideas between the two. In making his point, Leslie

discusses Stanford-related start-ups, including Hewlett-Packard, Varian Associates, Watkins-Johnson, Huggins Laboratories, and Granger Associates.³⁴ Leslie also notes the presence of satellite operations of firms based elsewhere, such as Lockheed, Sylvania, Philco, General Electric, and Westinghouse.³⁵ Like Saxenian, he discusses Stanford's industry outreach programs.³⁶ While Kenney and Saxenian discuss the Valley's activities from 1945 to 1965 as background for their more contemporary analysis, for Leslie the postwar period represents the heart of the matter. Leslie does not, however, assess the proportion of the activity in the Valley or Stanford's industry relations that involved start-ups versus established firms.³⁷

One of the principal points in an article Saxenian coauthored with Timothy Brensnahan and Alfonso Gambardella is that the Silicon Valley of the pre-1965 era offers a more sensible role model for developing regions than does today's Silicon Valley.³⁸ The period ending in 1965 was crucial for the development of the Valley. As Paul Rhode notes, "the high-technology sector in California broke away from the rest of the country during the late 1940s and 1950s."³⁹ The baseline for that takeoff, at least in the San Francisco Bay Area, was modest: as of 1939, the year Hewlett-Packard was founded, the Bay Area's combined total of salaried employees of manufacturers of electrical and radio equipment was 83, and total employment in those sectors was 464.⁴⁰ By 1963, however, electrical manufacturing employment in Santa Clara County alone stood at more than 17,000, representing nearly 20 percent of the county's total electrical manufacturing employment.⁴¹ The period 1940-1965 is clearly when the Valley reached high-tech critical mass and therefore represents a source of possible lessons for nascent high-tech regions.

So what was the role of the Valley's academic anchor in achieving high-tech critical mass? I will explore the development of Stanford University's early relationships with local high-tech industry, including Hewlett-Packard and Varian Associates, the companies primarily responsible for Stanford's reputation as an early promoter of entrepreneurship.⁴² Then I will discuss the four Stanford programs of outreach to local industry, revealing the extent to which each promoted entrepreneurship. Finally, I will review the activities of Frederick Terman after his retirement as Stanford's provost and discuss what his efforts on behalf of other regions reveal about the Stanford/Silicon Valley model.

Stanford, Terman, and Early Start-ups

During the five decades ending in the mid-1980s, Stanford rose from regional academic standing to world prominence in many fields, most notably in engineering and the sciences. At the same time, the geographical communities clustered around Stanford not only experienced phenomenal population growth, but also together became the world's leading center of high-tech entrepreneurship and of venture capital activity. During the early years of this transformation, Stanford University lacked an "administrative infrastructure" for cooperation with industry, so Frederick Terman was the principal agent in

building the relationship between Stanford and local high-tech industry from the 1930s to the 1960s. Along the way, Terman helped establish Stanford as what Henry Etkowitz defines as an "entrepreneurial" university through direct involvement in regional economic development via technology transfer.⁴³ Thanks in no small part to Terman's efforts, Stanford provided ample opportunities for local business to take advantage of the local academic anchor, earning him the moniker "father of Silicon Valley."⁴⁴

Hewlett-Packard and Varian Associates were the first two significant Stanford-related start-ups that stayed in the Valley rather than moving east. Both became symbols of what would become Stanford's major role in fostering local high-tech industry. In both cases, however, fostering entrepreneurship represented a last rather than a first resort for Frederick Terman and Stanford University. Terman's primary motivation was to build up the university, and it was an external predicament that made entrepreneurship an attractive option rather than any desire on the part of Terman or the university to promote start-ups.

Timothy Sturgeon demonstrates that the early (pre-1940) days of Silicon Valley featured elements that became familiar decades later: university involvement, entrepreneurship, and spin-offs from local firms.⁴⁵ In the 1920s and early 1930s, however, a number of the Bay Area's high-tech firms moved to Chicago or the East Coast.⁴⁶ Among them was Santa Clara County's first high-tech firm, the Federal Telegraph Company (FTC), founded in 1909 with the technical assistance of Stanford engineering professors and the financial backing of Stanford University's president, David Starr Jordan. FTC moved to New Jersey in 1932, taking away the region's greatest source of high-tech jobs. Sturgeon shows that some of FTC's engineers chose to stay in the Bay Area and start their own companies. The spin-offs were tiny, however, with total area engineering employment fewer than 100 jobs in the late 1930s.⁴⁷ In this respect, on the eve of World War II, Santa Clara Valley more represented what Martin Kenney calls an "already prepared environment" than a high-tech region.⁴⁸

Before Terman became dean of the school of engineering and before the rise of what would become Silicon Valley came a brain drain.⁴⁹ By the late 1930s, most of the local universities' engineering graduates (even the ones who wished to remain in the Bay Area) could find work only in the East with General Electric, RCA, Bell Labs, and Westinghouse. "The only way to escape [the fate of working on the East Coast] was to establish one's own business," recalled Terman, who chaired Stanford's electrical engineering department prior to World War II.⁵⁰ Terman wanted to help his graduates settle on the peninsula south of San Francisco and he wanted them to stay in touch with him (and with one another), establishing what he would later call a "community of technical scholars."⁵¹

It was in this environment that Terman helped his onetime students William Hewlett and David Packard rejoin that community. When they graduated in 1934, Packard, Hewlett, and two classmates had begun discussions about starting a company together.⁵² They postponed the idea, however, while Packard worked for General Electric in Schenectady, New York, and Hewlett earned a

master's degree at MIT. Both wished to return to the San Francisco peninsula, however, so Terman secured a fellowship for Packard at Stanford assisting Russell Varian to develop a microwave tube at the FTC spin-off Litton Laboratories. Terman also secured for Hewlett, whose only alternative was a job offer from a Chicago-based spin-off of FTC, a contract to develop hospital equipment.⁵³ Upon their return to Palo Alto, Hewlett and Packard began working together on their new company, establishing a partnership agreement in January 1939.

Among Terman's principal contributions to the new company were contacts with established firms. He provided Hewlett and Packard with a list of more than twenty potential customers. He also contacted the Stanford alumnus Harold Buttner, the vice president of research and development at International Telephone and Telegraph (ITT, the company that had acquired FTC). Buttner had worked for years with Terman to commercialize technology developed at Stanford, decades before the university created an office of technology licensing. Buttner helped secure a U.S. patent for Hewlett-Packard's first product (an audio oscillator) and paid five hundred dollars for foreign patent rights.⁵⁴ The ITT/HP relationship demonstrates the two facets of Terman's (and Stanford's) relationship with high-tech industry: working with indigenous start-ups (which has been well publicized), and working with established firms based elsewhere (which has not).

Although entrepreneurship in Santa Clara Valley helped compensate for the scarcity of large local firms in the case of HP, it compensated for the departure of a satellite operation of a large firm in the case of Varian. The Stanford professor William Hansen and his research associates Sigurd and Russell Varian invented the klystron (a microwave tube with potential military and commercial demand) in the physics department in 1937. The Varian brothers signed a contract with the university that allowed them access to the laboratory (and faculty members) in exchange for a share of returns from their inventions.⁵⁵ Stanford granted exclusive rights to the klystron to the Sperry Gyroscope Company in exchange for \$20,000 a year plus royalties.⁵⁶ The academic arrangement provided the Varians what they wanted most: access to lab equipment, sufficient money to run their experiments, and the autonomy to choose the scope of their research.

In late 1940, Sperry closed its West Coast operation and moved Hansen, Russell Varian, Edward Ginzton, and their lab associates to the company's Long Island laboratory to research defense-related uses of the klystron. During World War II, Ginzton approached Sperry management with a plan to establish a plant in Palo Alto at which the group would continue its work after the war. Sperry said no, and after the war the group returned to Stanford.

Their tenure at the university did not last long because the only available path to sufficient funding within the university was government-sponsored research, which meant that the government had considerable control over the way in which Stanford researchers worked. The U.S. Office of Naval Research dictated that the role of the physics department would be rather narrow. Furthermore, the sort of wide-ranging research the Varians preferred required a

free flow of information, yet their military work would have to be moved off campus in order to limit access to those with security clearances. Therefore, Varian Associates was established as an independent firm in 1948. Beginning an independent firm that performed defense contracts meant obtaining security clearance for the entire operation, but it also promised the opportunity to do basic research beyond immediate government needs. Ironically, as Timothy Lenoir notes, one of the primary reasons for the brothers' departure from the university and their establishment of Varian Associates was to safeguard their autonomy.⁵⁷

In the period before World War II, Stanford was actively involved in helping local inventors, whether they wished to start a company or simply to gain access to Stanford's laboratories. Yet, as Terman acknowledged, entrepreneurship seemed to be the only path available for establishing a local high-tech community and for providing work for graduates who wished to remain in the Bay Area. Those were the goals Terman cared about; fostering entrepreneurship was merely the means.

Stanford's Programs for High-Tech Industry

In the late 1940s, Stanford was a university with a regional reputation whose administrators entertained ambitions of something far greater. Such ambition required resources, and Stanford was strapped for cash. Stanford's financial predicament after World War II paralleled that of MIT after World War I. Faced with a combination of revenue constriction and rising enrollment, MIT established the Technology Plan, as one faculty member put it, to "capitalize the Institute's relations with industry."⁵⁸ For years, those relations had included the leading research-based firms in the United States, including AT&T, DuPont, and especially General Electric.⁵⁹ Although MIT helped establish start-ups (such as Raytheon), the university's more important relationships with industry were based on technology transfer, including consulting, disposition of patent rights, and contracts.⁶⁰

The Technology Plan represented an adaptive solution to an immediate problem. The industrialist George Eastman had offered the institute \$4 million if the institute landed matching gifts totaling \$3 million by January 1920. Falling short of that goal, the administration hastily organized the Plan, which involved contracts with nearly two hundred corporations, many of which were located outside the Northeast. Some of the companies were primarily interested in maintaining an employee pipeline of trained engineers, and others sought access to the institute's latest technological developments. The benefits to the university were undeniable: during the Technology Plan's first year, it funded one-third of MIT's budget. In the short term, the Plan succeeded: Eastman made his gift. There was no long term: the Plan died in 1929.⁶¹

One of MIT's graduate students during the Plan's infancy was Frederick Terman, and he was a keen observer. After becoming dean of Stanford's Engineering School in 1945, Terman pursued a two-pronged strategy of resource

accumulation. First, he pursued government contracts and grants, using MIT's success during World War II as a guide: MIT had capitalized on relationships with defense contractors such as GE and Westinghouse to garner a primary defense role.⁶² Second, he pursued industrial deep pockets all over the country, following the model he had observed while a graduate student at MIT. In the period from 1945 to 1965, when what would become Silicon Valley was attracting a critical mass of engineering and scientific talent, Terman helped to institutionalize relationships with established firms comparable to those he had observed at MIT. His efforts (and those of the university) to work with established firms have received far less attention than his efforts on behalf of start-ups, but they had a far broader institutional underpinning.

Stanford instituted four formal outreach programs to industry from the mid-1940s to the mid-1950s, and in all four, satellite operations of companies headquartered elsewhere were the principal industrial participants. Terman and his subordinates established two of the four (the Honors Cooperative Program and the Industry Affiliates Program) and helped to shape the third (the Industrial Park) after others did the initial spade work, and Terman himself acted as a key board member for the fourth (the Stanford Research Institute). Each of these programs served primarily to bring money to the university, and established firms were more likely than start-ups to have the deep pockets required to participate.

Stanford Research Institute

In his 1946-1947 annual report to the president of the university, Terman went beyond a summary of the Engineering School's accomplishments for the year and focused on what was necessary for regional economic development: "The West has long dreamed of an indigenous industry of sufficient magnitude to balance its agricultural resources. The war advanced these hopes and brought to the West the beginning of a great new era of industrialization. A strong and independent industry must, however, develop its own intellectual sources of science and technology, for industrial activity that depends upon imported brains and second-hand ideas cannot hope to be more than a vassal that pays tribute to its overlords, and is permanently condemned to an inferior competitive position."⁶³

This part of Terman's report has been frequently cited by scholars because of its apparent emphasis on the promotion of local start-ups, which is the perceived role of the "father of Silicon Valley." Yet the report also included another message, one that Terman featured in speeches to prominent businessmen in the West: "If western industry and western industrialists are to serve their own enlightened and long-range interests effectively, they must cooperate with western universities and, wherever possible, strengthen them by financial and other assistance."⁶⁴ This aspect of the relationship between Stanford and local industry during Silicon Valley's formative years has received little attention, although it played a central role during Terman's years as a Stanford administrator.

That sort of relationship with industry was behind the establishment of the Stanford Research Institute (SRI) in 1946. One of SRI's stated goals was to "to help develop industry in the West," but Stanford had selfish reasons for its creation as well. Stanford had scientists and engineers who could assist industry but lacked the resources to investigate industrial problems beyond the laboratory.⁶⁵ Meanwhile, industry could bring much-needed cash to universities in exchange for expertise.⁶⁶ SRI was one of several organizations established across the United States after the war to attract money to a university in exchange for faculty expertise in applied sciences and engineering. SRI was modeled on the Armour Research Institute in Chicago, which was affiliated with Armour Technical University (today's Illinois Institute of Technology); indeed, SRI hired away J. E. Hobson, the Armour Research Institute's director, in 1948.

Questions about the future of SRI were expected to "be answered under the conditions set by the economy of the West," especially "the extent to which the several west-coast industries can be regarded as potential sponsors of research at the Institute."⁶⁷ Not surprisingly, the board of SRI was, with the exception of the president of Stanford University, composed entirely of executives from California companies.⁶⁸

Reality turned out to be far different from the regional role expected of SRI. During SRI's first year in operation, less than 1 percent of its revenues came from sponsors in the Bay Area; more than three-fourths came from sponsors in the eastern United States.⁶⁹ Within ten years, less than 10 percent of its principal industry contacts had high-tech operations in Santa Clara County, and only one (Lenkurt Company) was locally owned. Meanwhile, government work—which represented 40 percent of SRI's revenue in 1950—came to dominate SRI's business after the beginning of the Korean War. From 1959 to 1965, about 75 percent of SRI's business was with the government.⁷⁰ This relationship would become a source of student protest during the Vietnam War and led to Stanford's 1969 decision to divest SRI.⁷¹

SRI's closest relationships with industry were through its Associates Program, which required a \$15,000 contribution from each company. Begun in 1949, the program provided Associates with copies of all SRI's non-confidential publications and invitations to an annual meeting discussing new SRI research.⁷² Associates accounted for more than half of SRI's commercial research revenue.⁷³ This did not come from indigenous high-tech firms. In 1955, five of SRI's 114 Associates had high-tech operations in Santa Clara County. Again, only one, Lenkurt Company, was independent and locally owned.⁷⁴ During the 1960s, not only did the Associates list—and the list of prospects to be contacted—look like the *Fortune* 500, but local firms continued to play a minor role.⁷⁵ Recent research suggests that SRI's experience is typical in at least one respect: to the extent that research institutes work with industry, it tends to be with larger firms.⁷⁶

Stanford Industrial Park

Stanford Industrial Park was Stanford's link with the local business community that involved the greatest degree of involvement (30 percent) by local

start-ups during the Valley's formative years. The genesis of the Park, however, was entirely a response to an internal university problem. Stanford's post-World War II financial woes contrasted sharply with its enormous land endowment of 8,800 acres. What do you do when you are land-rich and cash-poor, and when the terms of Leland Stanford's 1885 endowment of the university prohibited sale of the land? The solution, according to Stanford's president Wallace Sterling, was to put "idle lands to work"—to lease them.⁷⁷

At first, the purpose of the land use did not matter much to the university. After rejecting agricultural and residential (because of their limited revenue generation potential), the university proceeded on two fronts. The showcase project would become the Stanford Shopping Center; a relative afterthought—a place for light industry—became the Industrial Park. The Park would evolve organically over time from a purely moneymaking proposition to a high-tech haven.⁷⁸

By the time Sterling became president of Stanford in 1949, there were 50 industrial parks in America. What would be different in Stanford Industrial Park was the idea of a development devoted to research-based companies.⁷⁹ The initial screening of tenants for Stanford Industrial Park, however, had little to do with high technology. Tenants were simply required to use at least one acre and to follow Palo Alto's "light manufacturing" restrictions, and they were prohibited from running "smokestack" operations.⁸⁰ Consequently, the park's initial tenants, from 1954 to 1956, were a mixed bag. Along with the local companies, Varian Associates and Hewlett-Packard, were satellite operations of high-tech firms headquartered elsewhere, such as General Electric, Eastman Kodak, Admiral Corporation, and Beckman Instruments. In addition, there were branches of the publishers Houghton Mifflin and Scott, Foresman. In 1956, the university designated an additional 125 acres (beyond the existing 225) to accommodate Lockheed's Missiles and Space Division.⁸¹

By December 1960, the Park was more than ten times its original size and had thirty tenants.⁸² Of the thirty, nine (including HP and Varian) were local high-tech firms. An equal number (including GE and Lockheed) were branches of high-tech firms based elsewhere. Four were publishers and one was a book distributor. The tenants also included an architect, a realtor, a bank, and a mining company. In short, the Industrial Park provides little evidence of a university proactively sponsoring start-ups or nurturing them in their early years. Only a slight majority of the tenants engaged in high-tech activity at all. If the Park was part of anybody's vision for Stanford as midwife for high-tech entrepreneurship, that vision was far from realization in the early 1960s.

The Park's early years did foreshadow its later importance to Stanford in one respect. Terman expressed little interest in the Park at the outset, but belatedly became a booster. "Terman recognized the Park's potential after it opened," notes Henry Lowood, "and began then to work energetically behind the scenes to revise the course of existing plans."⁸³ Terman's interest in the Park increased when he realized that the Park's high-tech firms provided the university more in gifts than in lease revenue.⁸⁴

Honors Cooperative Program

The aspect of Stanford's relations with the local business community that was most purely a Terman initiative was the Honors Cooperative Program (HCP), a program Terman started in 1954, when he was dean of the engineering school.⁸⁵ In establishing the program, Terman may have been inspired by a program he observed as a graduate student at MIT. The MIT-GE cooperative course, which began in 1917, provided MIT students with shop-floor experience to complement their theoretical training in the classroom.⁸⁶ The Stanford program was a mirror image of the MIT program, providing employees of local companies the opportunity to supplement their work experience with rigorous academic training. W. Bernard Carlson notes that the MIT program provided "closer ties between the department and industry, leading to additional financial support and research opportunities" for the university.⁸⁷ The benefits to Stanford of its cooperative program were similar.

HCP, which by 1958 had expanded beyond engineering to the sciences and math, allowed employees of local companies to take regular classes and to work toward graduate degrees. In two calendar years, the employee would do a full year of graduate work, receive a master's degree, and continue to receive a full salary. Participating companies, which were each granted a limited number of spots in the program, agreed to pay fifteen dollars per course unit while continuing to pay their employees' full salaries. By 1959, 324 students, or more than 40 percent of the 750 graduate students in Stanford's school of engineering, were in the HCP. By 1962, the number of HCP participants had reached 500, still about 40 percent of the graduate program.⁸⁸

In addition to providing a very direct way for companies to benefit from cutting-edge knowledge transfer from the region's academic anchor, the principal advantage to participating companies was that it provided them with a competitive advantage in securing the best and the brightest employees in the sciences and engineering. The significance of participation is underlined by the behavior of Dean Watkins, a onetime Stanford engineering professor and a cofounder of Watkins-Johnson. In 1961, Watkins expressed a strong sense of urgency regarding his company's involvement in the program. Watkins had hired a promising employee with the understanding that the new hire would join the HCP. Unless Watkins-Johnson joined the program, Watkins feared losing the man—perhaps to a company that did participate.

An even more telling episode involved the Lenkurt Company, a local start-up that GTE acquired in 1959. During a visit with Fred Terman in 1960, Lenkurt's president expressed frustration at his difficulty in recruiting people who could meet the HCP qualifications. Terman then contacted the associate dean of industrial relations to see "if we can be of some special help." Terman's rationale: "Lenkurt is now part of General Telephone, as you know, and General Telephone can be quite important in Stanford's future. Hence, the importance of going out of our way to get in well with them." The implication is that larger companies were more precious to Stanford than local start-ups; here was a local

start-up that got Stanford's attention only after it had been acquired by a large Eastern firm.⁸⁹

The years for which the best information is available (from autumn 1956 to spring 1958) indicate that in this program, as with SRI and the Industrial Park, only a small fraction of participants were with local start-ups. During this period, 482 students participated in the HCP. Only 114, or less than one-quarter of the students, came from indigenous firms. The most active company in HCP was Lockheed, with 165 students. Among local firms, the most active was Hewlett-Packard, with 45 students.⁹⁰ The trend continued, and in 1963-1964, of 668 HCP students, less than one-quarter came from indigenous firms. Lockheed still dominated, with 155 students. Sylvania, with 92 students, also far exceeded HP's 55.⁹¹ HCP, an integral part of Terman's "community of technical scholars," relied more on established businesses headquartered elsewhere than on locally based firms.

Affiliates Programs in Engineering

The other program formalizing relations between Stanford and the local business community was the Affiliates Program in engineering. Of the various forms of outreach to local industry, the Affiliates Program was the one that came closest to pure fundraising. Each affiliate company contributed \$5,000 per year for five years to the program in which it participated. Terman acknowledged the program's existence in the netherworld between academics and fundraising during the planning stages. To differentiate it from a capital campaign, he noted: "There will be no public announcement, and no 'campaign' in the usual sense of that word. Each individual approach will be requested on the basis of enlightened self-interest rather than as an educational donation to Stanford because support of higher education is good. We would hope to put things in a framework such that the participating company could consider their annual contribution as a business expense if they wished, rather than as an educational contribution."⁹²

Like the Honors Cooperative Program, the Affiliates Program may have been inspired by what Terman observed at MIT. Just as Stanford's finances suffered from "chronic malnutrition" after World War II, so did MIT's after World War I.⁹³ During the 1920s, after establishing the Technology Plan, MIT followed up with the creation of a Division of Industrial Cooperation and Research, the purpose of which, notes AnnaLee Saxenian, was to "solicit corporate research contracts and keep companies apprised of MIT research findings."⁹⁴ This was essentially a combination of what Stanford would do with SRI and its Associates Program.

From 1950 to 1985, Stanford established 30 such liaison programs, primarily in the sciences, engineering, and business. During the Valley's formative years, two of the most significant were in solid-state electronics (a relatively new field at Stanford) and aerospace (a revival of a moribund program). Stanford's solid-state electronics program had begun in 1954 with the appointment of John Linvill. Drawing on his previous experience at MIT, in 1958 Linvill established

an industrial Affiliates Program.⁹⁵ The principal benefit to the companies in the solid-state program was access to faculty research prior to publication of results.⁹⁶ This included participation in an annual two-day technical review conference on campus, where faculty and industry representatives discussed new developments in the field. In addition, affiliates received all technical and progress reports issued by the faculty and graduate students in their program of choice, and invitations to faculty guest lectures. The principal benefit the university expected from the program was financial resources that would allow Stanford to expand its faculty by five or six members.⁹⁷

Although the initial discussions about the solid-state program were with representatives of local firms (Ampex, HP, and Lenkurt), the program was aimed both at companies that "are in the neighborhood and are interested in solid state electronics" and at companies "so important nationally in the field to be interested in seeing Stanford have a strong program even though they are not neighbors." The solid-state program's first seventeen affiliates included only four locally based firms. By 1965, there were still seventeen companies in the program, but only two (HP and Ampex) were local, and none of the top three additional prospects were local.⁹⁸

Meanwhile, a similar program had been established in the area of aerospace engineering. This program came on the heels of some pure fundraising. Terman was about to pull the plug on the aeronautical engineering division when a group of alumni offered to raise money from the aircraft industry to save it. The campaign resulted in pledges of \$130,000 from Douglas, Lockheed, Convair, Northrop, North American, and Hughes.⁹⁹ The additional resources paid off when Nicholas Hoff, a Stanford Ph.D., agreed to head the division.¹⁰⁰ Hoff, head of aeronautical engineering at Brooklyn Polytechnic Institute, joined the faculty at Lockheed's suggestion: the company feared he would reject its job offer unless it were accompanied by the Stanford affiliation.¹⁰¹

In 1959, Hoff launched an Affiliates Program, in which each firm pledged \$5,000 to \$10,000 per year for five years. Just as in the solid-state program, membership meant, in the words of the program proposal, "early dissemination of research information"—participation in an annual technical review and receiving copies of all departmental publications and theses. It also gave the companies an opportunity to meet graduating students, discuss their research, and assess their value as potential hires.¹⁰² The annual meeting became jokingly referred to as a "slave market," given the number of students hired by Affiliates.

As a satellite operation of a company based elsewhere, Lockheed was a typical Affiliate. Indeed, none of the original eight members of the aeronautical Affiliates Program were locally based. Although some of the names on the 1963 list were new, none of those eight were locally based either.¹⁰³ Writing to thank Lockheed for its support, Terman predicted that "a significant fraction of the graduate students we recruit from all over the country will one day work for Lockheed...your investment in Stanford Aeronautical Engineering has been justified."¹⁰⁴

The Centrality of Lockheed

When asked to name the companies that provided Santa Clara County's high-tech critical mass in the early years of its development, most people cite HP and Varian. Many are hard pressed to name a third. This is because the third company may be Lockheed. The fourth company may be IBM. The fifth may be GE. The sixth may be Sylvania. And so on. Stanford's programs of outreach to local industry, and their emphasis on larger firms based elsewhere, reflect the fact that locally based electronics firms were not large enough in the 1950s to provide the critical mass of brains and resources necessary to the development of the high-tech region. By 1955, the San Francisco Council of the West Coast Electrical Manufacturers Association had fifty-two members, some of whom had Stanford connections. Yet none of those firms—not the largest, Varian, nor the one with the brightest future, HP—had more than 1,000 employees. Only six had more than 500 employees.

By 1959, however, Lockheed, with 11,000 employees in the Valley, represented a far greater share of the area's high-tech brains than any other firm.¹⁰⁵ Lockheed had chosen a site in Sunnyvale for its Missiles and Space Division in 1956 in part because of its proximity to Stanford, and between 1956 and 1959 it had become the most active participant in Stanford's various outreach programs to industry.¹⁰⁶ Lockheed was one of SRI's early research clients, at a time (the early 1950s) when none of the firms indigenous to the Valley made that list.¹⁰⁷ By 1960, 1,500 people worked in Lockheed's Stanford Industrial Park laboratories, more than at any other firm except Hewlett-Packard and Varian, and the value of Lockheed's buildings there (\$4.5 million) was exceeded only by Varian's.¹⁰⁸ Lockheed had provided twice the level of support of any other firm for the revival of Stanford's aeronautical engineering program, and by 1959 had doubled the commitment of any other firm to the aeronautical Affiliates Program.¹⁰⁹ Lockheed also became an Affiliate of the solid-state program during its first year.¹¹⁰ Throughout the early years of the HCP (1956-1964), Lockheed sponsored more students than all indigenous firms combined. In the three academic years ending in 1962-1963, Lockheed gave Stanford nearly a half-million dollars, which represented gifts as well as grants to the university's various outreach programs.¹¹¹

The overall significance of Lockheed's role is captured in a seminal, prescient speech, "The Newly Emerging Community of Technical Scholars," which Terman delivered in 1963. The speech emphasized the increasing significance of the research university in the knowledge economy, and the importance of the relationship between the academic anchor and local industry. Terman mentioned that faculty members of Stanford's electrical engineering department held "some 15 directorships in profit making corporations," and "a few of these professors are well on the way to becoming millionaires as a result of stock holdings in companies founded by their students." Yet the longest segment of the speech was a direct quotation from Fritz Hollings, speaking on his retirement as governor of South Carolina. Hollings mentioned a recent visit he had made to Palo Alto, and instead of focusing on a start-up, he mentioned a satellite operation

of a company headquartered elsewhere: "There are more Lockheed employees in attendance at Stanford as graduate students than there are graduate students enrolled in science and engineering at the University of South Carolina. This division of Lockheed [in Sunnyvale] has 279 doctorates on its staff."¹¹²

Hollings's message was clear: South Carolina needed to beef up its research university. In so doing, the state would be in a better position to attract branches of large companies. Terman's point in using the Hollings quotation was that *he* believed this was the most important lesson to be learned from the post-war Stanford/Santa Clara County experience. To achieve critical mass, to establish a "community of scholars," required attracting branches of existing companies more than starting companies from scratch.

Santa Clara County achieved a critical mass of high-tech talent through attracting the satellite operations of established companies based elsewhere rather than through the establishment of local start-ups. These established companies played a critically important role in providing resources to the academic anchor, jobs to the brains trained there, and markets for high-tech research and development. Ironically, the Stanford model for what became known as the "entrepreneurial university" arose during a period when the university's relations with industry were dominated by established firms rather than start-ups.¹¹³

Conclusion

At the time that Stanford's programs of outreach to industry were dominated by established firms based outside of the Valley, the university's activities involving start-ups were quite limited. The establishment of Hewlett-Packard in the 1930s, Varian Associates in the 1940s, and Watkins-Johnson in the 1950s appear to support Stanford's continued role as an incubator. All three firms involved activity by Stanford professors (Dean Watkins kept his faculty appointment as he started Watkins-Johnson), and all three located in Stanford Industrial Park. Yet during the Valley's formative years, there was very little such activity beyond these three firms. One study of the Valley's 243 start-ups founded between 1960 and 1969 indicated that founders of only six had come from Stanford.¹¹⁴ It was not until after 1980 that Stanford professors and graduate students founded hundreds of firms, including Silicon Valley icons such as Silicon Graphics, Sun Microsystems, Cisco Systems, Yahoo, and Google. It was also in the 1980s that the default mode for Stanford engineering graduates became working in Silicon Valley rather than for eastern firms.¹¹⁵ Determining the reasons for these changes is grist for another study.

What about Frederick Terman, the "father of Silicon Valley?" He has been referred to as an academic entrepreneur, but this has more to do with his activities building Stanford University than in launching start-ups. Terman had indeed once employed a model of promoting entrepreneurship. That came, however, when he was in the department of electrical engineering and when the only option available for creating a community of scholars was to have his students start their own companies.

When Terman retired as Stanford University's provost in 1965, he hit the road to bring the Santa Clara County magic to the world. His most visible efforts at creating communities of technical scholars were in New Jersey, Texas, and Korea. Yet in none of these cases did his proposals even mention entrepreneurship; instead, he proposed establishing new universities to interact with existing high-tech enterprise.¹¹⁶ Stuart Leslie and Robert Kargon remark, "Ironically, the man who had helped launch dozens of start-ups and seen some of them grow into corporate giants now seemed to have forgotten them completely."¹¹⁷ Terman's consulting priorities had little to do with amnesia, however; instead, he employed a model similar to what he had used during the formative years of Silicon Valley.

What lessons can we draw from Stanford's relations with high-tech industry during Silicon Valley's formative years? It is popular now to look at today's Silicon Valley—the foremost incubator of high-tech entrepreneurship the world has seen—as something that can be replicated quickly. Aspiring high-tech regions deduce what elements seem to make up a formula for success—a concentration of brains, an entrepreneurial culture, and an infrastructure supportive of high-tech and entrepreneurial activity—and conclude that if they create these elements, they can become the next Silicon Valleys. At the heart of such plans, often, is an academic anchor that is expected to spark regional economic development as a midwife to start-ups.¹¹⁸

The long-run benefits of such a strategy are clear: a strong local high-tech presence with intense loyalty to the academic anchor. One need only stroll around the Stanford campus to see the benefits accruing to the university of Terman's efforts to help William Hewlett and David Packard build something lasting from their humble beginnings in Packard's garage. The implication is that with enough such garages, a thriving high-tech region will emerge. Yet during the region's formative years, Stanford's relations with local industry had another emphasis entirely: on building relationships with established companies. Perhaps Terman's efforts on behalf of start-ups have been overemphasized to reflect the entrepreneurial direction the Valley subsequently took.

It may be that successful incubation of firms is a natural role for the academic anchor, but not an immediate one. Universities are never far from financial crisis or at least budget concerns, and therefore when building high-tech capabilities and programs, they are reliant on deep pockets. Certainly since the 1940s, in America the federal government has represented a major source of university funding. Yet in the formative years of an academic anchor, its primary relations with industry are likely to include established firms that are able and willing to part with financial resources in exchange for technology or talent. This is why it is important to heed the point made by Bresnahan, Gambardella, and Saxenian regarding which Silicon Valley represents the most useful model for much of the world.¹¹⁹ For those trying to establish a high-tech region elsewhere, the lesson may be *not* to try to replicate Silicon Valley's contemporary university-industry relationship and the central role of entrepreneurship. Rather, the Valley's

formative years offer a different model for the contributions of an academic anchor to the development of a nascent high-tech region.

Notes

1. A. Markusen, "Sticky Places in Slippery Space: A Typology of Industrial Districts," *Economic Geography*, 72/3 (1996): 293-313.
2. T.A. Stewart, *Intellectual Capital* (London: Nicholas Bradley, 1997).
3. L. Leydesdorff and H. Etkowitz, "A Triple Helix of University-Industry-Government Relations," in H. Etkowitz and L. Leydesdorff, eds., *Universities and the Global Knowledge Economy: A Triple Helix of University-Industry-Government Relations* (London: Pinter, 1997), pp. 155-162.
4. Nathan Rosenberg and Richard R. Nelson explore the question of the division of technological labor between universities and industry. N. Rosenberg and R.R. Nelson, "American Universities and Technical Advance in Industry," *Research Policy*, 23 (1994): 323-348. The present article, by contrast, attends to the division of roles between indigenous enterprise and firms based outside Silicon Valley in their dealings with Stanford University.
5. J.F. Gibbons, "The Role of Stanford University: A Dean's Reflections," in C-M. Lee, W.F. Miller, M.G. Hancock, and H.S. Rowen, eds., *The Silicon Valley Edge: A Habitat for Innovation and Entrepreneurship* (Stanford, CA: Stanford University Press, 2000), p. 205.
6. T. Byers, R. Keeley, A. Leone, and G. Parker, "The Impact of a Research University in Silicon Valley; Entrepreneurship of Alumni and Faculty," *Journal of Private Equity*, 4/1 (Winter 2000): 7-15.
7. C.-M. Lee, W.F. Miller, M.G. Hancock, and H.S. Rowen, "Silicon Valley Habitat," in C-M. Lee, W.F. Miller, M.G. Hancock, and H.S. Rowen, eds., *The Silicon Valley Edge: A Habitat for Innovation and Entrepreneurship* (Stanford, CA: Stanford University Press, 2000), p. 1.
8. The sources I use regarding these four outreach programs include annual reports for SRI and Stanford's School of Engineering; memoranda, press releases, and articles of incorporation explaining the goals and operations of the programs; lists of companies participating (including acreage and numbers of employees for the industrial park, and names of each student for the Honors Cooperative Program); correspondence of the principals, especially Frederick Terman; and Terman's speeches. These documents are primarily found in the papers of the Stanford School of Engineering; the papers of Terman, who served as dean of the engineering school (1945-1958) and as university provost (1955-1965); and the papers of Wallace Sterling, president of the University (1949-1968)—all located at the Stanford University Archives, Special Collections (SC). Henceforth in these notes, the Terman papers are abbreviated as SC 160; the Engineering School papers as SC 165, and the Sterling papers as SC 216.
9. D.A. Kaplan, *The Silicon Boys and Their Valley of Dreams* (New York, NY: Morrow, 1999), pp. 157, 13.
10. J. Zhang, *High-Tech Start-Ups and Industry Dynamics in Silicon Valley* (San Francisco, CA: Public Policy Institute of California, 2003), pp. 1, 11.
11. A. Saxenian, *Regional Advantage: Culture and Competition in Silicon Valley and Route 128* (Cambridge, MA: Harvard University Press, 1994), p. 2.
12. The National Science Foundation and the Alfred P. Sloan Foundation funded the Silicon Valley Cultures Project. J.A. English-Lueck, C.N. Darrah, and A. Saveri, "Trusting Strangers: Work Relationships in Four High-Tech Communities," *Information, Communication, and Society*, 5/1 (2002): 90-108; Kaplan, *Silicon Boys*, pp. 13-14.
13. David Teece wrote about foreign direct investment in Silicon Valley in the 1970s and 1980s. D.J. Teece, "Foreign Investment and Technological Development in Silicon Valley," *California Management Review*, 34/2 (Winter 1992): 88-106. Many companies active in the Valley during the 1950s and 1960s represented domestic direct investment from beyond the region.
14. Among the countries attempting to follow the Silicon Valley model have been Mexico, Brazil, Japan, South Korea, Malaysia, and China. M.I. Rivera Vargas, *Technology Transfer via Industry-University Relationship: The Case of the Foreign High Technology Electronics Industry in Mexico's Silicon Valley* (New York, NY: RoutledgeFalmer, 2002); J. Epstein, "Brazil Strives to Tempt Settlers to a 'Silicon Valley,'" *Christian Science Monitor*, April 12, 1995, p. 8; "Japan's Silicon Valley," *Interface*, 9/1 (2000): 16; M. Quan, "Plans Shape Up for South Korean Silicon Valley," *Electronic Engineering Times*, July 26, 1999, p. 32; J. Markoff, "Silicon Valley of the

- East? Try Malaysia," *New York Times*, January 20, 1997, p. D4; "Yangtze Delta Becoming China's Silicon Valley," *China Today*, 42/10 (1993): 65.
15. Kaplan, op. cit., p. 25; J.A. Mathews, "A Silicon Island of the East: Creating a Semiconductor Industry in Singapore," *California Management Review*, 42/2 (Winter 1999): 55-78; R.T. Abdel Jaber, "Silicon Wadi: Can Jordan Develop an Internationally Respected and Competitive Software Industry?" *Jordan Times*, April 8, 1999; D. Dearlove, "Europe Needs Its Own Silicon Valley," *The Times* [London], September 27, 2001; S. Josifovska, "Silicon Valley North," *IEE Review*, 49/5 (May 2003): 22-24; J.A. Schofield, "Silicon Valley, Meet 'Silicon Glen': Technology and Geography Combine to Make Scotland Europe's High-Tech Crossroads," *Design News*, March 27, 1995, pp. 65-69.
16. B. Metcalfe, "Asian Tour Provides Useful Insight on Silicon Valley's Worldwide Internet Edge," *Info World*, March 2, 1998.
17. A. Marshall, *Principles of Economics* (London: Macmillan, 1968); M. Piore and C. Sabel, *The Second Industrial Divide* (New York, NY: Basic Books, 1984); M. Bellandi, "The Industrial District in Marshall," in E. Goodman and J. Bamford, eds., *Small Firms and Industrial Districts in Italy* (London: Routledge, 1989), pp. 136-152; M. Porter, "Cluster and the New Economics of Competition," *Harvard Business Review*, 76/6 (November/December 1998): 78. See also M. Porter and S. Stern, "Innovation: Location Matters," *MIT Sloan Management Review*, 42/4 (Summer 2001): 28-36.
18. Leading examples include P. Cooke, *Knowledge Economies: Clusters, Learning and Cooperative Advantage* (London: Routledge, 2002); P. Cooke, M. Heidenreich, and H. Braczyk, eds., *Regional Innovation Systems: The Role of Governance in a Globalized World* (London: Routledge, 2004); J.H. Dunning, ed., *Regions, Globalization, and the Knowledge-Based Economy* (New York, NY: Oxford University Press, 2000).
19. Cooke, op. cit., p. 194. Overall, popular accounts appearing from the mid-1970s to the mid-1980s not only emphasized both the prominent role Stanford played in the region's early development and the entrepreneurial nature of the region, but tended to configure them as cause and effect (*post hoc ergo propter hoc*). G. Bylinsky, "California's Great Breeding Ground for Industry," *Fortune* (June 1974), pp. 128-132; D. Hanson, *The New Alchemists: Silicon Valley and the Microelectronics Revolution* (Boston, MA: Little, Brown, 1982); E.M. Rogers and J.K. Larsen, *Silicon Valley Fever: Growth of High-Technology Culture* (New York, NY: Basic Books, 1984); M.S. Malone, *The Big Score: The Billion-Dollar Story of Silicon Valley* (Garden City, NY: Doubleday, 1985).
20. Saxenian notes that Stanford "actively promoted local technology start-ups during the years following World War II." Saxenian (1994), op. cit., p. 8. Kenney notes that existing organizations "did not espouse the economic goal of encouraging and nurturing spin-offs, even though the activities of Frederick Terman did encourage them from Stanford." M. Kenney and U. von Burg, "Institutions and Economies: Creating Silicon Valley," in M. Kenney, ed., *Understanding Silicon Valley: Anatomy of an Entrepreneurial Region* (Stanford, CA: Stanford University Press, 2000), p. 223. Leslie notes that Terman "strongly encouraged an aggressively entrepreneurial culture," and referred to him as "the man who had helped launch dozens of start-ups and seen some of them grow into corporate giants." S.W. Leslie and R.H. Kargon, "Selling Silicon Valley: Frederick Terman's Model for Regional Advantage," *Business History Review*, 70 (Winter 1996): 436-437, 463-464.
21. A. Saxenian, "The Genesis of Silicon Valley," in P. Hall and A. Markusen, eds., *Silicon Landscapes* (Boston, MA: Allen & Unwin, 1985), pp. 35-48; A. Saxenian, "In Search of Power: The Organization of Business Interests in Silicon Valley and Route 128," *Economy and Society*, 18/1 (February 1989): 25-70; A. Saxenian, "Regional Networks and the Resurgence of Silicon Valley," *California Management Review*, 33/1 (Fall 1990): 89-112; A. Saxenian, "The Origins and Dynamics of Production Networks in Silicon Valley," *Research Policy*, 20 (1991): 423-437; A. Saxenian, "Contrasting Patterns of Business Organization in Silicon Valley," *Environment and Planning D: Society and Space*, 10 (1992): 377-391; Saxenian (1994), op. cit.; A. Saxenian, "The Limits of Autarky: Regional Networks and Industrial Adaptation in Silicon Valley and Route 128," in W. M. Fruin, ed., *Networks, Markets, and the Pacific Rim: Studies in Strategy* (New York, NY: Oxford University Press, 1998), pp. 273-292; A. Saxenian, "Networks of Immigrant Entrepreneurs," in C-M. Lee, W.F. Miller, M.G. Hancock, and H.S. Rowen, eds., *The Silicon Valley Edge: A Habitat for Innovation and Entrepreneurship* (Stanford, CA: Stanford University Press, 2000), pp. 248-268; A. Saxenian, "The Role of Immigrant Entrepreneurs in New Venture Creation," in C.B. Schoonhoven and E. Romanelli, eds., *The Entrepreneurship Dynamic: Origins of Entrepreneurship and the Evolution of Industries* (Stanford,

- CA: Stanford University Press, 2001), pp. 68-108; A. Saxenian, "Taiwan's Hsinchu Region: Imitator and Partner for Silicon Valley," in T. Bresnahan and A. Gambardella, eds., *Building High-Tech Clusters: Silicon Valley and Beyond* (New York, NY: Cambridge University Press, 2004), pp. 190-228.
22. Saxenian (1994), op. cit., p. 8.
23. Ibid., p. 27.
24. Ibid., p. 23.
25. Ibid. p. 208.
26. M. Kenney, *Biotechnology: The University-Industrial Complex* (New Haven, CT: Yale University Press, 1986); M. Kenney and R. Florida, "Venture Capital-Financed Innovation and Technological Change in the US," *Research Policy*, 17/3 (1988): 119-137; M. Kenney and R. Florida, "Silicon Valley and Route 128 Won't Save Us," *California Management Review*, 33/1 (Fall 1990): 68-88; M. Kenney and U. von Burg, "Technology, Entrepreneurship and Path Dependence: Industrial Clustering in Silicon Valley and Route 128," *Industrial and Corporate Change*, 8/1 (March 1999): 67-103; M. Kenney, ed., *Understanding Silicon Valley: Anatomy of an Entrepreneurial Region* (Stanford, CA: Stanford University Press, 2000); M. Kenney and U. von Burg, "Paths and Regions: The Creation and Growth of Silicon Valley," in R. Garud and P. Karnoe, eds., *Path Dependence and Creation* (Mahwah, NJ: Lawrence Erlbaum Associates, 2001), pp. 127-148; M. Kenney and W.R. Goe, "The Role of Social Embeddedness in Professional Entrepreneurship: A Comparison of Electrical Engineering and Computer Science at UC Berkeley and Stanford," *Research Policy*, 33 (2004): 691-707; D. Meyer and M. Kenney, "Economic Action Does Not Take Place in a Vacuum: Understanding Cisco's Acquisition and Development Strategy," *Industry and Innovation*, 11/4 (December 2004): 299-325; M. Kenney and D. Patton, "The Co-Evolution of Technologies and Institutions: Silicon Valley as the Iconic High-Technology Cluster," working paper, 2005.
27. Also emphasizing the "ecosystem" in another high-tech region is Mathews (1999), op. cit.
28. Kenney and von Burg (1999), op. cit., p. 73.
29. Kenney and von Burg (2001), pp. 223-224.
30. Ibid., p. 229.
31. Ibid., pp. 225-226.
32. R. Kargon, S.W. Leslie, and E. Schoenberger, "Far Beyond Big Science: Regions and the Organization of Research and Development," in P. Galison and B. Hevly, eds., *Big Science: The Growth of Large-Scale Research* (Stanford, CA: Stanford University Press, 1992), pp. 334-354; S.W. Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford* (New York, NY: Columbia University Press, 1993); S.W. Leslie, "The Biggest 'Angel' of Them All: The Military and the Making of Silicon Valley," in M. Kenney, ed., *Understanding Silicon Valley: Anatomy of an Entrepreneurial Region* (Stanford, CA: Stanford University Press, 2000), pp. 48-67.
33. Leslie has examined the role of academic anchors in other regions as well—emphasizing the difficulty of establishing another Silicon Valley. Leslie and Kargon (1996), op. cit.; K. Dong-Won and S.W. Leslie, "Winning Markets or Winning Nobel Prizes? KAIST and the Challenges of Late Industrialization," *Osiris*, 13 (1998): 154-185; S.W. Leslie, "Regional Disadvantage: Replicating Silicon Valley in New York's Capital Region," *Technology and Culture*, 42 (April 2001): 236-264.
34. Leslie, op. cit., pp. 64-71.
35. Ibid., pp. 114-132. Others have emphasized the role of established firms in the development of Silicon Valley. See M. Gray, E. Golob, A. Markusen, and S.O. Park, "New Industrial Cities? The Four Faces of Silicon Valley," *Review of Radical Political Economics*, 30/4 (1998): 1-28; B. Harrison, "Concentrated Economic Power and Silicon Valley," *Environment and Planning A*, 26 (1994): 307-328; T. Heinrich, "Cold War Armory: Military Contracting in Silicon Valley," *Enterprise and Society*, 3/2 (June 2002): 247-284.
36. Leslie, op. cit., pp. 66, 68, 102, 121, 128-129, 173-174, 243-247.
37. Also emphasizing this period is Christophe Lécuyer. Lécuyer focuses on the Valley's signature industry of semiconductors. He argues that the Valley's academic anchor, Stanford University, played little role in the development of semiconductors; instead, he suggests the impact the industry has had on the university. C. Lécuyer, "Making Silicon Valley: Engineering Culture, Innovation and Industrial Growth, 1930-1970," Ph.D. dissertation, Stanford University, 1999; C. Lécuyer, "Fairchild Semiconductor and Its Influence," in C-M. Lee, W.F. Miller, M.G. Hancock, and H.S. Rowen, eds., *The Silicon Valley Edge: A Habitat for Innovation and Entrepreneurship* (Stanford, CA: Stanford University Press, 2000), pp. 158-183;

- C. Lécuyer, "What Do Universities Really Owe Industry? The Case of Solid State Electronics at Stanford," *Minerva*, 43 (2005): 51-71.
38. T. Bresnahan, A. Gambardella, and A. Saxenian, "'Old Economy' Inputs for 'New Economy' Outcomes: Cluster Formation in the New Silicon Valleys," *Industrial and Corporate Change*, 10/4 (December 2001): 835-860; S. Venkataraman, "Regional Transformation through Technological Entrepreneurship," *Journal of Business Venturing*, 19/1 (January 2004): 156.
39. P.W. Rhode, *The Evolution of California Manufacturing* (San Francisco, CA: Public Policy Institute of California, 2001), p. 26.
40. U.S. Bureau of the Census, *Census of Manufactures, 1939*, vol. 3, *Area Statistics* (Washington, D.C.: Government Printing Office, 1942), pp. 104, 106.
41. U.S. Bureau of the Census, *Census of Manufactures, 1963*, vol. 3, *Area Statistics* (Washington, D.C.: Government Printing Office, 1966), pp. 5-25.
42. Much of the academic literature on Silicon Valley emphasizes the role Stanford played in establishing high-tech start-ups, beginning with Hewlett-Packard in 1939 and Varian Associates in 1947. Saxenian (1994), op. cit., p. 20; Leslie and Kargon (1996), op. cit., p. 439; and Lee, Miller, Hancock, and Rowen (2000), op. cit., p. 1.
43. H. Etkowitz, "Making of an Entrepreneurial University: The Traffic among M.I.T. and the Industry and the Military, 1860-1960," in E. Mendelsohn, M.R. Smith, and P. Weingart, eds., *Science, Technology and the Military* (London: Kluwer Academic Publishers, 1988), p. 520.
44. For a biography of Terman, see C. Stewart Gillmor, *Fred Terman at Stanford: Building a Discipline, a University, and Silicon Valley* (Stanford, CA: Stanford University Press, 2004).
45. T.J. Sturgeon, "How Silicon Valley Came to Be," in M. Kenney, ed., *Understanding Silicon Valley: Anatomy of an Entrepreneurial Region* (Stanford, CA: Stanford University Press, 2000), pp. 15-47.
46. D. Packard, *The HP Way* (New York, NY: Harper Business, 1995), p. 23; Sturgeon, op. cit., p. 35.
47. U.S. Bureau of the Census, *Census of Manufactures, 1939*, vol. 3, p. 104; F. Terman, "Bay Area Electronics—Then and Now," speech delivered November 20, 1973, Stanford University Archives, Special Collections (SC) 160, VIII, 4, 5, p. 1.
48. M. Kenney, "Introduction," in M. Kenney, ed., *Understanding Silicon Valley: Anatomy of an Entrepreneurial Region* (Stanford, CA: Stanford University Press, 2000), p. 4.
49. S.B. Adams, "Regionalism in Stanford's Contribution to the Rise of Silicon Valley," *Enterprise and Society*, 4/3 (September 2003): 528.
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